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Description of a Monitoring System for Shutdown Nuclear Reactors

Script of a Briefing given by a United States Expert to the Members of the Delegations to the ENDC at the United States Mission, August 10, 1966.

INTRODUCTION

Distinguished Delegates: I have been requested to describe to you the system developed within the United States of America for effectively and unobtrusively monitoring a shutdown nuclear reactor and ascertaining that it has not been operated between infrequent periodic inspections. The system I will describe is one which the United States suggests will satisfactorily perform the desired degree of surveillance with a minimum of intrusion.

The monitoring of a shutdown reactor is possible with an inspection system which utilizes a completely passive device, which once installed may remain in place for years, unless removed for an inspection.

Selection of the word "passive" in describing the monitoring system serves primarily to indicate the manner in which the system operates. Passive means that it does not require operation in the sense of moving parts, electronic instrumentation, attachments, and other devices subject to malfunctions which might adversely affect the integrity of the monitoring system. Passive may also properly describe the other advantages of the method, since the entire system is inoffensive, unobtrusive, makes no permanent attachments, nor in any way affects the integrity of future use of the facility.

The reactor monitoring system is based on the ability to detect and measure neutrons generated by an operating reactor. Detection utilizes the effect of a neutron on a material which captures the neutron. The operation of a nuclear reactor generates a tremendous quantity of neutrons in the core. For clarification, slide #1 provides a graphic representation of a fission reaction, with a neutron particle released from the nucleus of an atom, such as Uranium 235. The ragged lines indicate the path of a fast neutron through a moderating material, gradually slowing down to a point where it is captured, in one case by an atom of Uranium 238, which is subsequently altered to Plutonium 239. Another neutron wanders a similar path and is captured by another atom

of Uranium 235, causing it to fission. This generates more neutrons for continuation of the reaction. Into this situation we have introduced a safing wire, or tape, for the purpose of detecting whether there has been any neutron activity. This shows in the upper right hand corner of the slide. A small amount of cobalt in the tape captures some of the neutrons, converting the natural cobalt 59 to cobalt 60. We use cobalt because it is a good material for capturing neutrons. In addition, cobalt 60 has a half life of 5½ years. This means that its emission of high energy gamma rays will not be significantly altered during the periods the tape is apt to be left in place. The telltale gamma rays are the key to this monitoring system. Thus, small quantities of cobalt inserted in a sufficient number of locations can effectively monitor an <u>entire</u> reactor, or any part of it large enough to sustain a nuclear reaction.

The method of fabricating the tape is shown in slide #3. Two cobalt alloyed aluminum wires and two thin tantalum wires are inserted through a stainless steel tube. Only one-tenth percent cobalt in an aluminum alloy is necessary. Note in the slide how the tantalum wire is twisted and looped back on itself. The reason for this is to produce a random configuration of the tantalum wire throughout the length of the tape. The assembly is then rolled and flattened to the thin rectangular shape shown below the tube assembly. Slide #4 illustrates how a complete length of tape is rolled on a cardboard drum for handling and for "fingerprinting", that is, obtaining an x-ray photograph of the tape. Slide #5 is a section of the x-ray taken of the tape as coiled on the drum I have just shown. This x-ray provides the record against which each centimeter of tape can be checked for identity and damage. This image or "fingerprint" illustrates the primary means by which we identify system components and determine any tampering with various parts of the safing system. The stainless jacket has a high melting temperature. The aluminum core has a low melting temperature. The bi-metallic combination of the two provides additional assurance against a successful compromise of the system.

The safing tape may be installed in fuel channels, such as shown in slide #6, core coolant tubes, control rod thimbles, or other penetrations of the reactor core which are an integral part of the reactor. In utilizing the system, the Host Nation will provide a liner tube which will be inserted in agreed upon locations. This liner protects the reactor components from any deleterious effects, such as corrosion from

the safing tape, and also protects the tape from surface contamination, corrosion, or other damage. The end seal connected to the safing tape is illustrated in slide #7. The seal assembly is further shown in the exploded view in slide #8. Here we see an additional protective liner inserted in the host liner tube. It may also be fabricated to have its own unique "fingerprint".

The safing tape is pulled through the aluminum plate and clamped securely in place with a collet or clamp. The plastic cap assembly is then installed over the clamp. Pieces of wire are mixed at random within this plastic cap. Not illustrated is an epoxy sealant which is applied to various parts during the assembly and provides a final seal over the exterior bolt holes and other seal openings. The sealant is also fingerprinted with randomly added lead and metal shavings, pieces of wire and other particles distinctive in size and shape. The finished seal assembly is shown from the front in slide #9 and from an angle in slide #10. The angle photograph is preferred for the fingerprint record of the seal since it provides a perspective view. Slide #11 illustrates the x-ray of the seal assembly and clearly shows the random orientation of the inclusions which identify the seal and the sealant, and facilitates detecting any damage to the seal.

Slide #13 is a view of a reactor face with three seal assemblies in place. A closer view is shown in slide #14, with the exterior safing tape visible between the seal assemblies and then disappearing from view toward the top of the reactor. The external safing tape may be used to secure vital reactor controls, thereby monitoring the operation of these components as well. The exterior safing tape differs from the tape used inside the reactor core in that it contains no cobalt in the tape core and the jacket consists of copper rather than stainless steel. Fully annealed, the copper tape is very pliable and lends itself to the various wrapping and threading operations. Essential to the use of the exterior safing tape is the joining seal, which allows the connexion of tape ends and other junctions, illustration of which are shown in slides #15 and #16. The joint seal is fingerprinted with inclusions in the body of the plastic piece and is sealed with the epoxy sealant.

Installation of a safing tape which protrudes from both ends of the tube or channel through the reactor is quite simple: a seal assembly is attached to each end of the tape. For a reactor, which because of its design permits access only to a single face, a different way to guarantee that the tape remains in the reactor had to be found.

Slide #12 shows this type of reactor and presents a concept in which a control thimble is used. The host liner tube would in this instance be given a more active role. The end to be inserted into the access hole would support a jaw device which when properly installed in the monitoring location would be actuated by the safing tape attached to the jaws to force them to spread and engage in a suitable opening, or aperture, in the reactor structure. The seal assembly would again protect the safing tape to prevent release of the jaws and removal of the monitoring system.

It is expected that a team composed of four competent members, fully familiar with the procedures, will be able to complete a safing installation and record the necessary photographic and x-ray fingerprints in a period of two days to a week. The team would complete indexing and filing of the information taken during the safing installation upon return to their home base. The periodic inspection will probably require a similar period of time, two days, if the inspection proves routine and no major interpretive problems occur.

The method by which the team records a seal installation is illustrated on slide #17. This photograph shows the camera in position to record a perspective view of the seal. The adjustable arm attached to the safing plate allows an exact positioning of the camera, which is critical for the subsequent photographs to be taken on follow-up inspections.

Supplementing the noran photographs is the x-ray picture. Slide #18 illustrates the x-ray tube positioned to x-ray the seal from the side. The portability of the equipment makes it easy to get at various reactor seals.

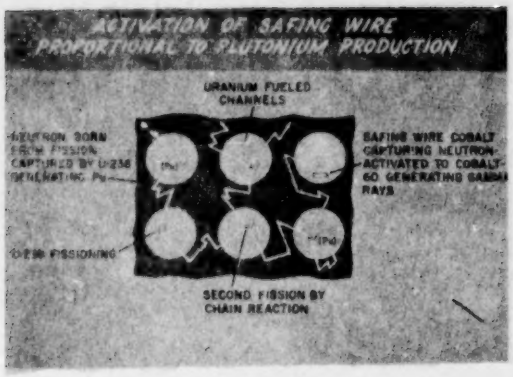
Supplementing the photographic and x-ray equipment is an eddy current probe and recording device which can be utilized to supplement the remaining system with a different inspection tool. The team may on the initial installation make a record of various sections of the safing tape for future comparisons. Slide #19 shows the equipment, and slide #20 illustrates the result of a test performed with this equipment. In the test, a sample of safing tape was x-rayed and checked with the eddy current probe. The line drawn by the eddy current sensor has hardly a ripple in it. The piece of tape was then carefully cut and rejoined by butt welding. The joint was difficult to discern visually. Inspection of the x-ray, however, shows a considerable displacement of the tantalum wire, evidently occurring when the aluminum was partially melted. When the welded section of tape passes through the eddy current probe, it produced a very sharp and detectable signal. This sensitive behaviour has shown up consistently in a number of tests.

The reliability of the system depends on the inspection procedure by which the seal assemblies and other safing components are inspected. The inspection team members would carefully review the photographs and x-rays taken on each visit and compare them with the previously taken record or file copies. The team would utilize overlay techniques to compare photographs and x-ray prints. Projected on the screen are two pictures taken on Polaroid transparancies. In perfect overlay they look like one picture. As one slide is moved in relation to the other, the corresponding similarities stand out for comparison. A similar technique is shown with x-ray prints in overlay and the patterns are seen to compare directly.

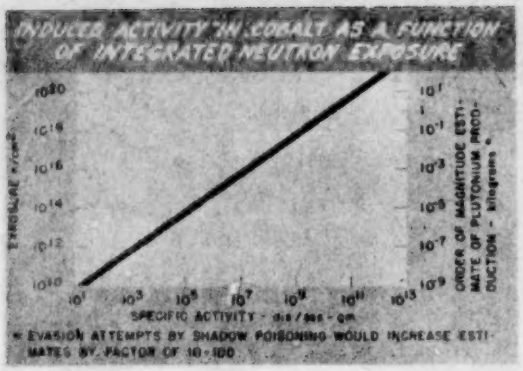
With the field equipment required by the team being easily portable, any view of a seal and any section of the safing tape can be recorded for file information. Subsequent to the initial inspection of the safing installation, the team can select at random one or more of the safing tapes to be removed from the reactor and monitored for neutron activation. The seal is broken off and the collet released. The tape is then withdrawn from the tube liner with a team member carefully monitoring for radio-activity. The tape can then be carefully inspected for any evidence of tampering. The removed tapes will be replaced in the same liner or installed in a new location at the discretion of the inspection team. The replacement safing tape will be sealed and recorded as described earlier.

The presentation which I have made today is, at best, only a brief summary of the concept of the passive safing seal. A complete systems manual has been prepared which fully details the safing concept, materials, their application, and the organization and operation of the international inspection team. These manuals were prepared after the initial development phase was completed and are quite comprehensive. The contents include the scope and intent of the monitoring seal, the nuclear physics involved, a proposed inspection team organization, the procurement specifications of the safing tape and safing seal, and the composition of the inspection team's field equipment. The manual additionally describes installation techniques, photographic and x-ray inspection methods, and the use of other aids, such as the eddy current device to insure backup of the other procedures. The manual will be of considerable assistance to anyone interested in more detail than can be covered in this particular presentation.

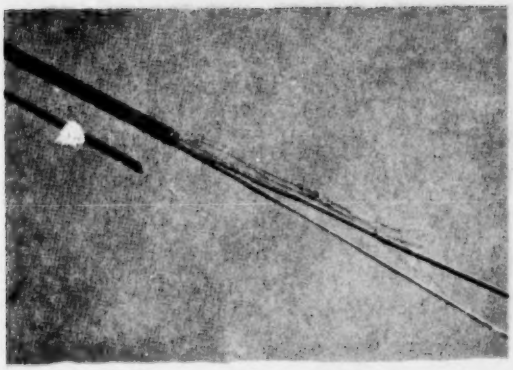
My main concern is that I have conveyed to you a clear picture of how the system functions and the merits of our approach. I will be happy to entertain any questions at this time. Thank you.


ACTIVATION OF SAFING WIRE
PROPORTIONAL TO PLUTONIUM PRODUCTION
URANIUM FUELED CHANNELS
NEUTRON BORN FROM FISSION CAPTURED BY U-238 GENERATING Pu
SAFING WIRE COBALT CAPTURING NEUTRON ACTIVATED TO COBALT-60 GENERATING GAMMA RAYS
U-235 FISSIONING
SECOND FISSION BY CHAIN REACTION

1


INDUCED ACTIVITY IN COBALT AS A FUNCTION OF INTEGRATED NEUTRON EXPOSURE
SPECIFIC ACTIVITY - dis / sec - gm
ORDER OF MAGNITUDE ESTIMATE OF PLUTONIUM PRODUCTION - kilograms
* EVASION ATTEMPTS BY SHADOW POISONING WOULD INCREASE ESTIMATES BY FACTOR OF 10-100

2



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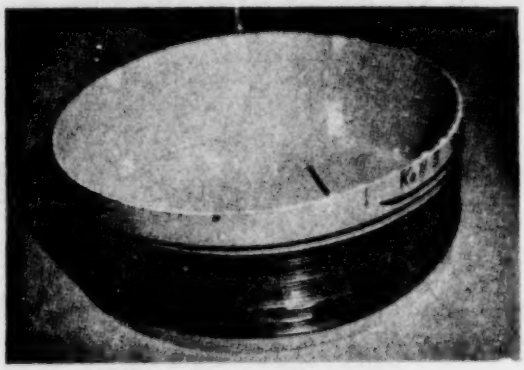

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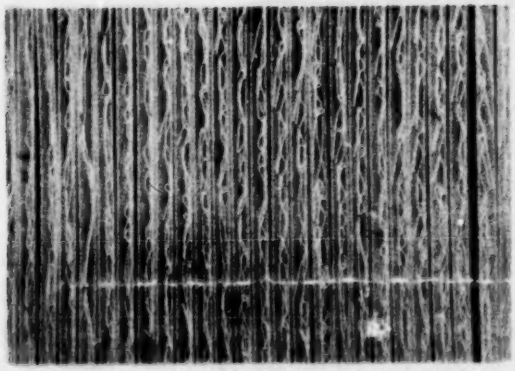

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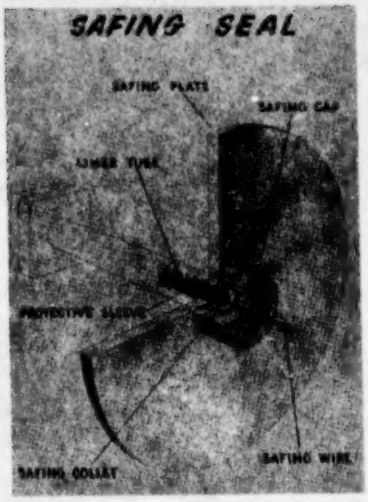
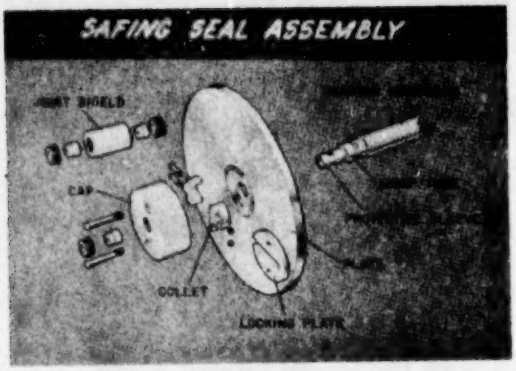
TYPICAL INSTALLATION OF SAFING SEAL
SYSTEM ON A REACTOR OF F TYPE

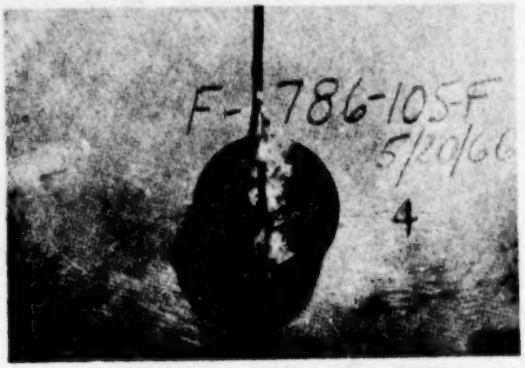
6


SAFING SEAL
SAFING PLATE
SAFING CAP
LINER TUBE
PROTECTIVE SLEEVE
SAFING COLLET
SAFING WIRE

7


SAFING SEAL ASSEMBLY
CAP
COLLET
LOCKING PLATE

8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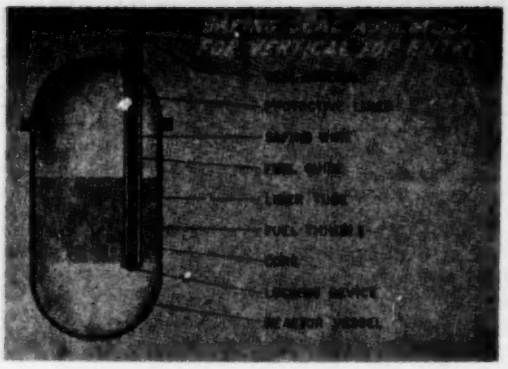

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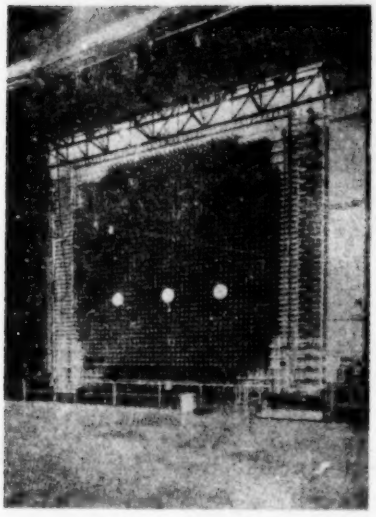

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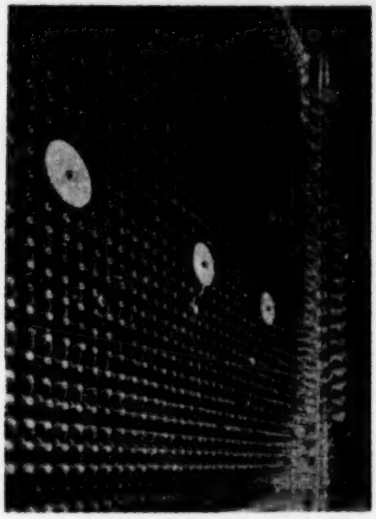

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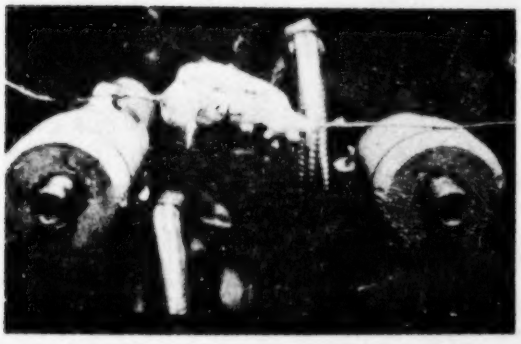

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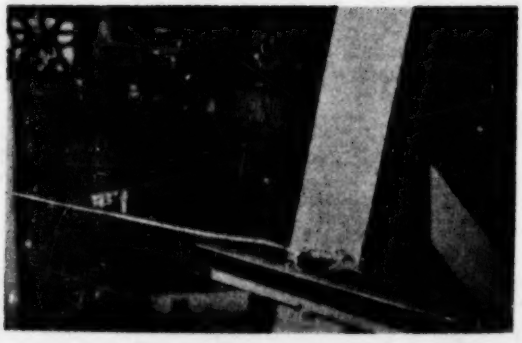

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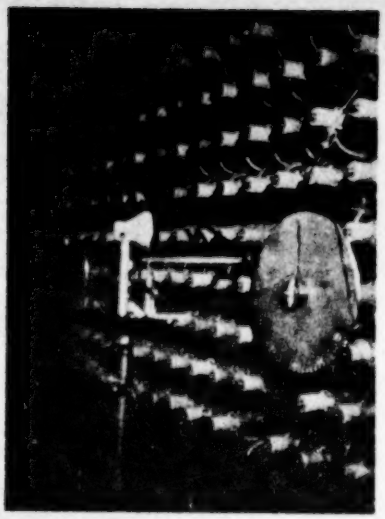

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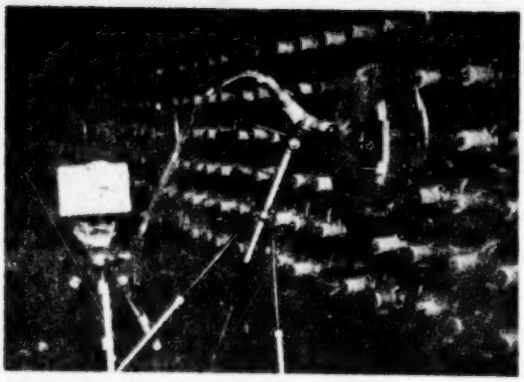

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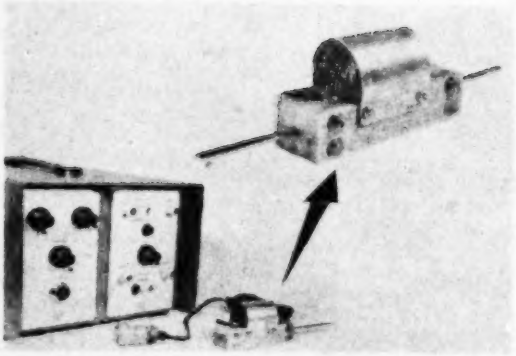

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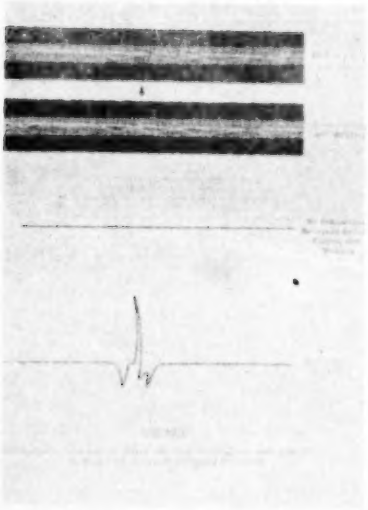

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